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Results of Fingerprint Image Quality Experiments

R. T. Moore

Institute for Computer Sciences and Technology
U.S. Department of Commerce
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, ***Secretary***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

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RESULTS OF FINGERPRINT IMAGE QUALITY EXPERIMENTS

R. T. Moore

A series of experiments were conducted to determine the variation in the scores developed using a matching algorithm designated as the M-82 for mating fingerprints of different image quality that had been read by the Automatic Fingerprint Reader System (AFRS) of the FBI. The variations in image quality resulted from the use of a variety of card stocks and recording techniques to record the print of a single finger. For each image recording process, a sample of 56 finger-pairs were matched and mean single-finger score values were developed. These varied over a factor of more than 70 to one. The best scores were developed from images placed on very white, slick appearing, calendered card stock with the use of film strips that had been pre-inked and which could be separated to expose an ink film of predetermined thickness and uniformity. This combination had less resistance to smearing than fingerprints produced on the same stock from the use of a pre-inked porous pad. However, the latter still produced acceptably high scores.

Key words: Fingerprint cards; fingerprint images; fingerprint ink; image quality.

INTRODUCTION

In the course of developing material for future use in an instruction manual that is intended to help improve the overall quality of fingerprint images that are submitted to the FBI for processing, it was observed that images produced using a commercially available, pre-inked, porous pad appeared to yield somewhat lower matching scores than those produced using a film of ink rolled on a glass plate. This observation motivated the development of a series of experiments in which a variety of card stock materials and inking or recording techniques could be examined in order to develop estimates of their effects on the scores that resulted from a computerized matching process . This process uses the minutiae that are detected by machine reading different impressions of the same fingerprint. In these experiments, every effort was made to minimize the influence of variables other than ink and paper. All images were of a single finger, the author´s number seven. Plain prints, rather than rolled, were taken so as to minimize plastic deformation and the likelihood of smudging or smearing. Care was taken to center the prints in the fingerboxes of the fingerprint card using a common orientation in order to minimize the influences of possible misregistration, and every effort was made to produce the highest quality image possible. Images were made using some combination of four different types of card stock and four different inking techniques. In addition, three types of card stock were used with an inkless chemical fingerprint recording process.

The types of card stock that were used in the experiment are shown in Table I

TABLE I

1. An extremely white, calendered, stock that is used by the Department of Police, Identification Unit, Saint Paul, Minnesota.

2. The "standard" FBI criminal fingerprint card (printed in red).

3. A calendered version of the FBI criminal fingerprint card.

4. The "standard" FBI applicant fingerprint card (printed in blue).

The inking techniques that were used in the experiments are shown in Table II.

TABLE II

1. Pre-inked plastic strips that are separated immediately prior to use so as to expose an ink film that had been mechanically applied in a smooth, uniform layer of predetermined thickness.

2. A newly purchased, commercially available, porous, pre-inked pad such as those available form the usual suppliers of fingerprinting materials.

3. A pad identical to the one described above, but approximately six years old, although only lightly used.

4. Printers ink, rolled to a film, on a glass plate.

5. An inkless pad, treated with a chemical substance which would react with other chemicals previously applied to the card stock to leave a visible fingerprint image.

DATA RECORDING

In December 1980, fourteen fingerprint cards of data were recorded. For each card, the author's number seven fingerprint, an ulnar loop, was recorded in each of the ten finger boxes. The following steps were followed in each instance:

1. The finger was washed thoroughly with warm water and soap, rinsed, and dried with a paper towel; then it was allowed to air dry for two minutes more.

2. The finger was placed on the ink (or chemical) source surface and pressed moderately (about 0.1 newton force) with little or no rolling motion; then it was lifted straight off of that surface.

3. The finger was centered over the fingerbox on the fingerprint card, and then lowered straight down to leave a plain impression that was not rolled. Force used in depositing the impression was comparable to that used in inking the finger.

4. The finger was lifted straight up off the card and residual ink was removed by thoroughly wiping the finger with absorbent paper tissue.

5. Steps 2, 3 and 4 were repeated untill all ten fingerboxes were filled.

DATA PROCESSING

After all 14 cards of data had been recorded, the fingerprints were matched by a computer using the M82 algorithm. Since the M-82 algorithm is arranged to match eight of the ten fingerprints (fingers number five and ten are excluded) normally recorded on a fingerprint card with their counterparts on a second card, an artifact was introduced to avoid changing the normal processing routine. The minutiae list for finger number one of card number one was inserted in finger positions 1, 2, 3, 4, 6, 7, 8, and 9 so as to form an artificial fingerprint card having identical minutiae data in each of the eight finger boxes that are processed by the M82 matching algorithm. This artificial fingerprint card was called, "CNO 1 FNO 1" and was matched against each of the fourteen real fingerprint cards. This process was then repeated for finger number two of card number one (producing CNO 1 FNO 2), etc., to create the artificial search deck of 112 fingerprint cards that was matched against all other cards.

In each of these 112 card matchings, the fingerprint that was used to create the artificial card would be matched against itself in one instance. This would produce an extremely high "identity" score which is meaningless and which was discarded. In its place a score was substituted that was the mean of the scores of the other seven fingers that were different impressions of the same finger, but which were obtained using the same fingerprint recording process. The total card score (RST) for this artificial card was the RST score indicated by the matcher minus the "identity" finger score, times eight-sevenths. In other words, it is assumed that the "identity" score could be replaced by a score equal to the mean score of each of the other seven fingers on the card. The RST value was calculated in this way for each of the 112 cards in the search deck. Their mean and standard deviation were then calculated. The single-finger mean score for each card and ink type was then taken to be one eighth of the mean of the corrected RST score for that type.

Although 56 pairs of fingerprints were matched to develop the single-finger mean score, only 28 of these were unique. This is because "a" matched against "b" produces the same score as "b" matched agianst "a".

Identification of the cards is shown in Table III.

TABLE III

CNO	Recording process and type of card stock
1.	Inkless (chemical process) on calendered and machine coated FBI criminal card.
2.	Inkless on brush coated FBI criminal card.
3.	Pre-inked plastic strip on St. Paul calendered card.
4.	Pre-inked plastic strip on calendered FBI criminal card.
5.	Pre-inked plastic strip on standard FBI criminal card.
6.	New pre-inked porous pad on St. Paul calendered card.
7.	New pre-inked porous pad on calendered FBI criminal card.
8.	New pre-inked porous pad on standard FBI criminal card.
9.	Old pre-inked porous pad on St. Paul calendered card.
10.	Old pre-inked porous pad on calendered FBI criminal card.
11.	Old pre-inked pad on standard FBI criminal card.
12.	Ink rolled on glass on St. Paul calendered card.
13.	Ink rolled on glass on calendered FBI criminal card.
14.	Ink rolled on glass on standard FBI applicant card.

RESULTS

The results of the experiment are shown in tabular form below:

TABLE IV

CNO	RST MEAN	STD. DEV.	%	1 FING. MEAN	DRs	DRi	PCS
1	3,824	1,203	31	478	.84	.18	.81
2	151	73	49	19	.81	.20	.75
3	11,099	3,479	31	1,387	.93	.12	.86
4	6,609	2,253	34	826	.85	.17	.80
5	6,540	1,590	24	817	.88	.17	.81
6	5,789	2,112	36	723	.93	.12	.87
7	5,300	1,397	26	662	.86	.15	.83
8	655	137	21	82	.82	.22	.80
9	7,098	2,189	31	887	.93	.19	.80
10	3,602	1,011	28	450	.86	.20	.77
11	423	160	38	53	.87	.25	.71
12	2,641	940	36	330	.93	.18	.81
13	1,685	588	35	211	.86	.17	.80
14	612	196	32	76	.86	.20	.77

In the foregoing tabulation, the column labeled "%" is the percentage that the Standard Deviation is of the Mean RST. As such, it provides an indication of the width of the distribution curve.

The " 1 FING. MEAN" column is one-eighth of the RST MEAN.

The column labeled "DRs" shows the diffuse reflectivity of the card stock measured with a commercially available reflectometer using a spot of white light having a diameter of 0.2 mm (0.008 in.). It is interesting to note that the St. Paul calendered card stock has an indicated reflectivity of 0.93. The white tile that was used to calibrate the reflectometer had a reflectivity of only 0.91.

The column labeled "DRi" shows the diffuse reflectivity of the ink (or dye) as observed in a 0.2 mm spot selected to be in the center of one of the darkest ridges on the card. The reflectivity indicated by the reflectometer is reported to be much less accurate for dye markings than for pigment markings. Printers ink forms pigment based (carbon black) markings. The basis for markings produced by the pre-inked

porous pad and by the chemical recording process is not known.

The column labeled "PCS" shows the Print Contrast Signal as computed using the relationship

$$PCS = \frac{(DRs) - (DRi)}{(DRs)}$$

In general, the value of PCS was higher for those cards that scored well than for those that scored poorly, but there is too much variability to support the use of PCS as a valid predictor of scoring performance. For example, CNO 4 with a mean RST of 6,609 had a PCS of 0.80, while CNO 6 with a mean RST of 5,789 had a PCS of 0.87.

Much of this variation in PCS is believed to result from the fact that small changes in the position of the sampling spot of the reflectometer can produce large changes in the value of DRi. One might speculate that use of a larger sampling spot, or some other means of getting a better representation of "average" ink reflectance, might provide more useful information.

Also, it is likely that a more meaningful estimate of scoring performance might be developed through the use of diffuse reflectance measurements made using illumination having wavelengths better matched to the spectral characteristics of the flying spot scanner that is used in the Automatic Fingerprint Reading Systems.

Table V shows the identity of the cards when ranked by mean single-finger scores in the first column. The second column lists the cards in order of subjective impression of their image quality.

TABLE V

CNO Ranked by Score	CNO Ranked Subjectively
3	3
9	4
4	6
5	9
6	5
7	7
1	10
10	1
12	12
13	13
8	14
14	8
11	11
2	2

Note that the subjectively ranked cards are surprisingly close to the order that was established by ranking in accordance with score.

Figure 1 shows the mean single finger-pair scores of these 14 cards grouped by the type of inking that was used. The highest scores were obtained when the pre-inked plastic film strips were used. In these examples, the St. Paul calendered card stock provided the highest scores, and the standard FBI card stock gave the lowest scores, for each of the respective inking processes.

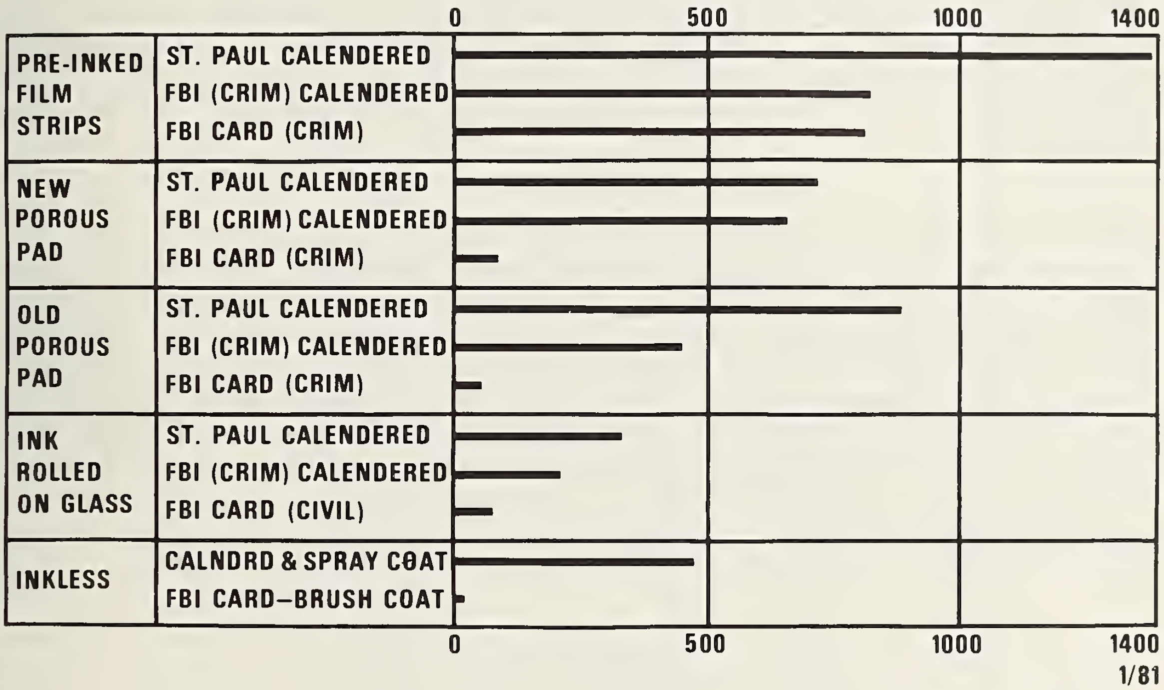

Figure 1. Mean single finger-pair scores vs. type of inking.

In order to provide an estimate of the performance that would result when search and file prints were of different

quality, the scores were evaluated when the three highest quality cards, CNO 3, 4 and 5, were matched against CNO 14 (rolled ink on a standard FBI criminal card). In each instance, the mean, single finger, matching pair score was an intermediate value that was greater than the value for CNO 14, but less than the values for CNO 3, 4 or 5. CNO 3 vs. CNO 14 yielded a value of 203; CNO 4 vs. CNO 14 produced a value of 176; and CNO 5 vs. CNO 14 gave a mean, single finger, matching pair score of 154.

These results would tend to support the assertion that improved matcher performance would be obtained by using search fingerprint cards of higher image quality even though the quality of the file cards might be poorer and not subject to upgrading.

Upon reviewing the foregoing data, it was noted that CNO 14 was an applicant (blue printed) card whereas the other standard (non-calendered) FBI cards had all been of the criminal (red printed) type. Also, the mean scores produced by this card had been somewhat lower than had been expected. Therefore, on January 22, 1981, six more cards were prepared. These cards were given a CNO that was 100 greater than the CNO of their direct counterpart in each case where such a counterpart existed in the first data set.

They are identified in Table VI.

TABLE VI

CNO	Recording process and type of card stock
103.	Pre-inked plastic strip on St. Paul calendered card.
105.	Pre-inked plastic strip on FBI criminal card.
112.	Ink rolled on glass, St. Paul calendered card.
114.	Ink rolled on glass, FBI applicant card.
115.	Ink rolled on glass, FBI criminal card.
116.	Pre-inked plastic strips, FBI applicant card.

The fingerprints were recorded on these cards using procedures that were, to the greatest extent possible, identical to those used in recording the images on the first set

of cards. The objectives in recording this second set of cards were to see if there were any differences in the performance of the FBI applicant and criminal cards, and to develop estimates of the reproducibility of the results when every effort was made to use identical techniques at different times.

Subsequent to recording fingerprint images on these six cards, samples of a St. Paul calendered card stock were received that had been coated for recording images with the inkless chemical process used on CNO 1 and CNO 2. A sample of this card stock was recorded and assigned the identification CNO 0. It was processed along with the additional six cards described above.

The results of processing these seven cards are shown in Table VII.

TABLE VII

CNO	MEAN RST	STD DEV.	%	1 FING. MEAN
0	1,572	485	31	197
103	5,267	933	18	658
105	4,058	1,360	34	507
112	7,173	1,435	20	897
114	415	206	50	52
115	1,968	860	44	246
116	2,891	578	20	361

Figure 2 shows the comparison of some of the results obtained from the impressions made in December 1980 and those made in January 1981. There is considerable variation in the results that were obtained from the same process on the two different occasions. This occurred even though care had been exercised in attempting to maintain consistency in recording the data each time.

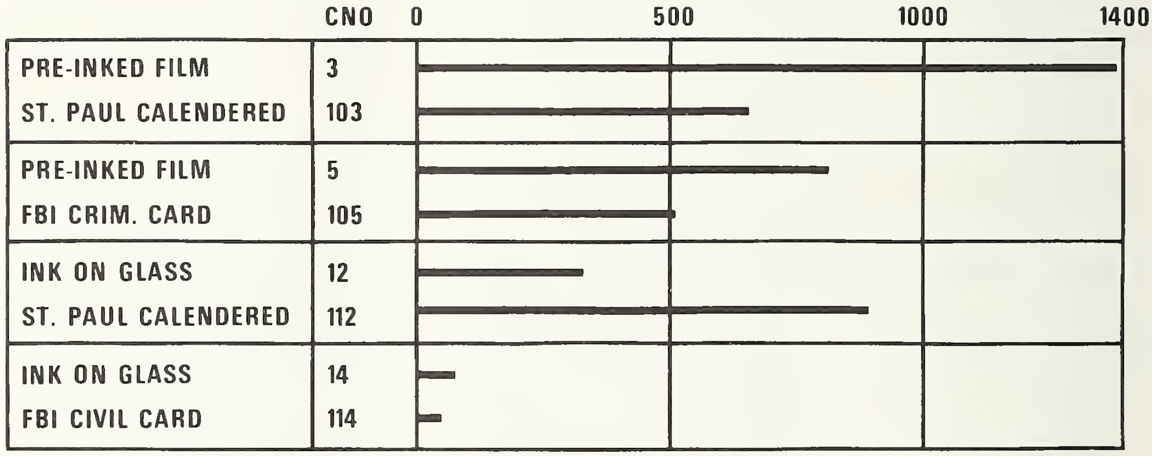

Figure 2. Comparison of score repeatability.

In order to try to determine reasons for some of the wide differences in mean finger-pair scores that were obtained

from the different processes, two pairs of prints were selected for detailed analysis. The highest scoring individual pair of fingerprint impressions from CNO 3 was FNO 2 vs. FNO 3. They attained a score of 2500, nearly twice the mean value for the card. On CNO 11, FNO 1 vs. FNO 7 was the highest scoring pair at a value of 130. These were the four images that were selected for detailed examination.

Plots were made at 10x enlargement of the minutiae that were detected on each of the four fingerprints. These were compared with the fingerprint images using both direct optical and photographic 10x enlargements. Minutiae that were subjectivly judged to be true minutia were identified. In general, there were about four or five false minutiae detected on each of the CNO 3 images and about 30 true minutiae and eight or ten true minutiae were not detected by the automatic reader. On the CNO 11 images, there were approximately the same numbers of true minutiae detected and missed, but there were many more false detections; 11 on one image and 26 on the other.

Tracings were made of the 10x scale plots of those true minutiae that were common to both CNO 3 images (FNO 2 and FNO 3). There were 27 of these. The tracings were then superimposed on each other in a subjectively determined "best fit" position and the straight line displacement distance between each mating pair of minutia was measured. Figures 3 and 4 show these two fingerprints and Figure 5 shows the plot of superimposed minutiae. The results of the displacement measurements are shown in Table VIII.

TABLE VIII

Displacement (mm at 10x)	Number of occurrences
0	7
1	11
2	6
3	2
7	1

Total minutiae = 27 Weighted mean displacement = 1.33 mm

Figure 3. CNO 3 FNO 2

Figure 4. CNO 3 FNO 3

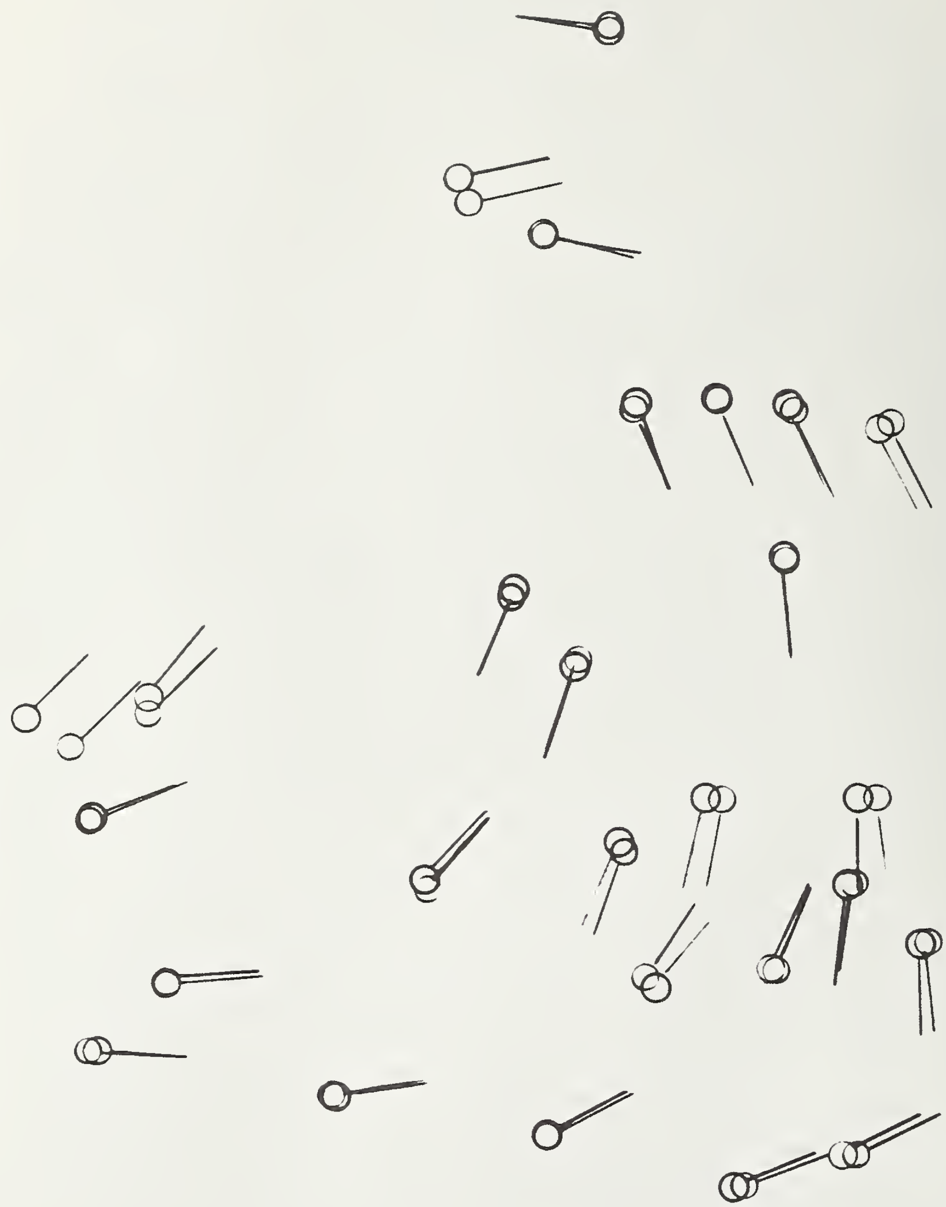

Figure 5. Superimposed plot of common minutiae.

The same procedure was followed for FNO 1 and FNO 7 of CNO 11, see Figures 6, 7, and 8.

Figure 6. CNO 11 FNO 1

Figure 7. CNO 11 FNO 7

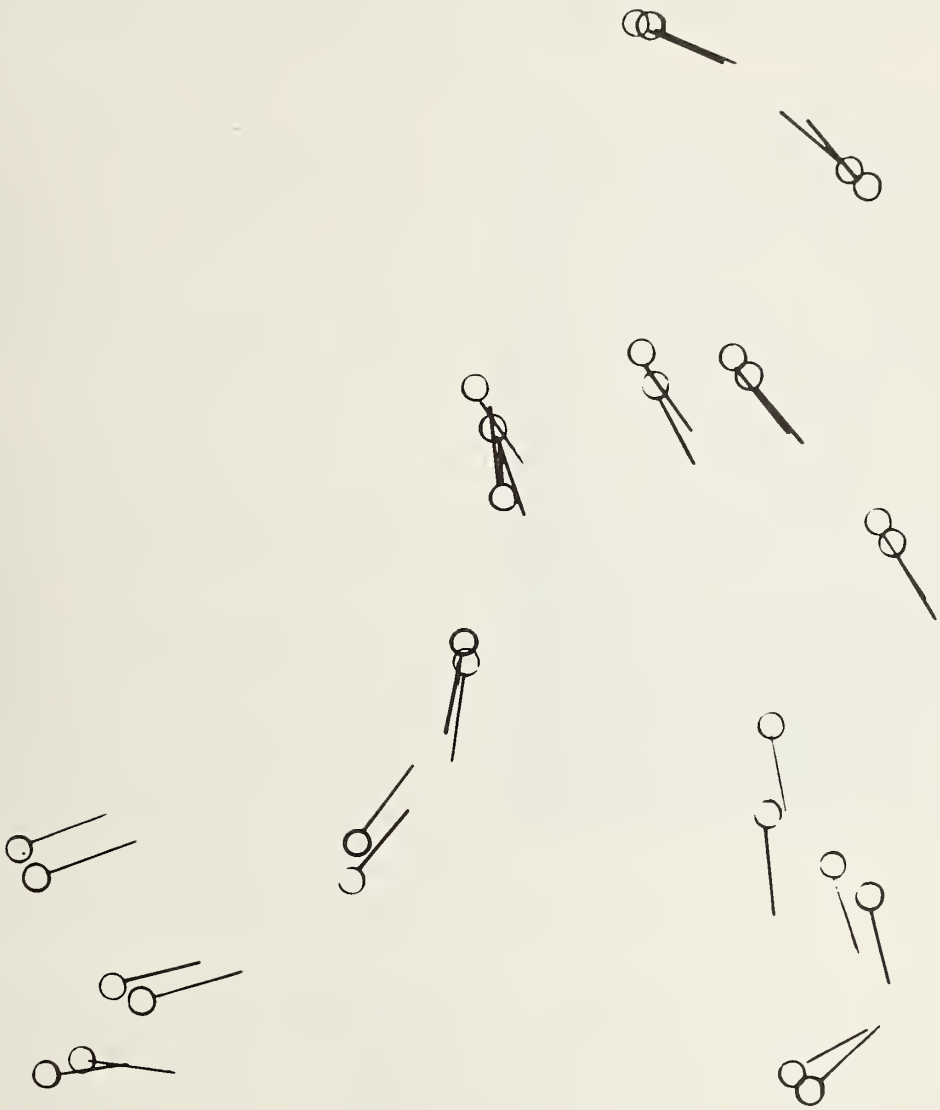

Figure 8. Common minutiae of CNO 11.

In this CNO 11 example there were only 15 true minutiae that were common to both images. Their displacement distributions were also much more spread as shown in Table IX.

TABLE IX

Displacement (mm at 10x)	Number of occurrences
0	0
1	4
2	3
3	3
4	2
5	1
6	1
7	1

Total minutiae = 15 Weighted mean displacement = 3.0 mm

In comparing the data from these two cards, CNO 3 has matching minutia pairs that are twice as numerous, and a little more than twice as closely collocated as CNO 11. On the other hand, CNO 11 had a larger total number of minutia than CNO 3 because of the many false detections. These increase the value of the denominator of the equation that is used in the M 82 matcher to develop the score. Collectively, these features contribute to the development of scores for the two sets of fingerpairs that differ by a factor of 19 times.

Study of these card images and their minutia plots reveals a suggestion of a pattern to the displacement distributions and an indication of a posssible cause. In the case of CNO 3, the edges of the ridges are relatively sharply defined. There are minor breaks in the inking that appear to be caused by pores or other features that inhibit perfect contact between the surface of the friction ridges of the finger and the smooth calendered card stock. When mating minutiae are detected on different impressions in positions that are displaced from each other, they are often displaced in a direction that is normal to the ridge direction. Frequently the amount of the displacement suggests the transition of a minutia from being detected as a ridge ending in one reading to a bifurcation in the other reading. An example of this is shown in Figure 9, a 20x photomicrograph of a portion of a fingerprint on CNO 3. Depending upon the processing of the digital filter in the fingerprint reader system, this image might result in the detection of either a ridge ending or a bifurcation at the approximate positions

indicated in the figure. The displacement in position that would result if the feature was detected as a ridge ending on one reading and a bifurcation on the other reading would be on the order of 0.4 to 0.5 mm on the unenlarged image.

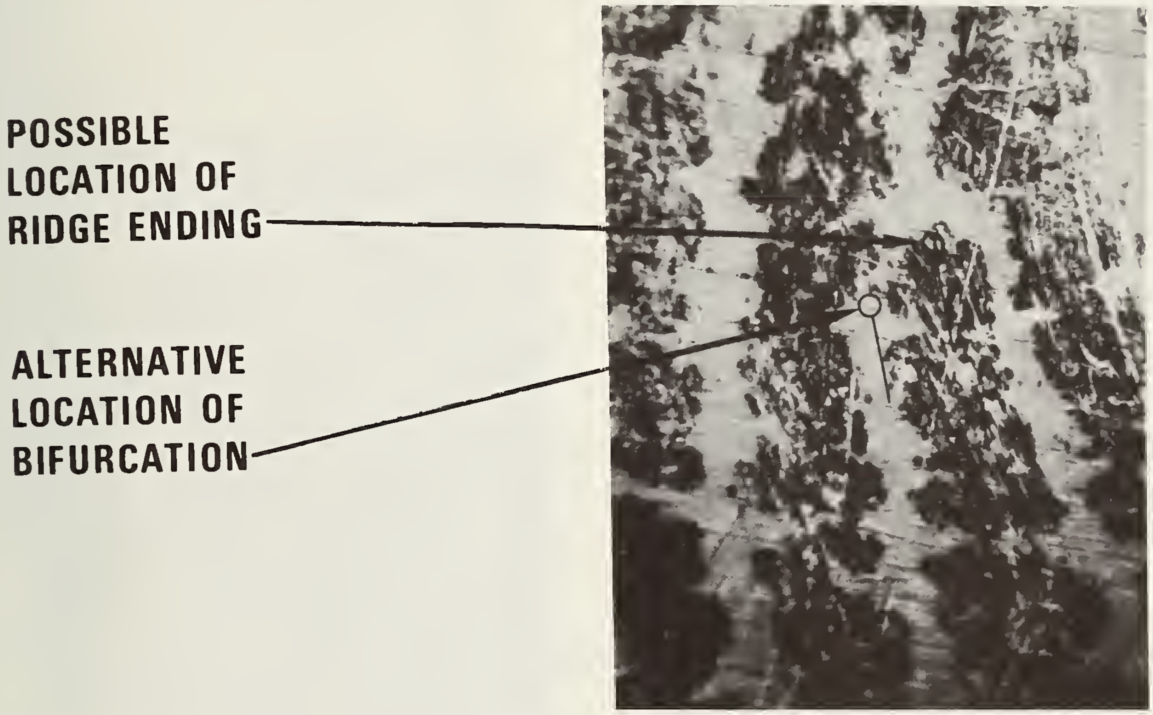

Figure 9. CNO 3

On CNO 11, the displacements appear to occur more often in a direction that is parallel to the ridge direction. On this card the edges of the ridges are more fuzzy. The ink appears to have been deposited more heavily on those fibers of the card stock that are farther from the surface, while depressed regions between these fibers received lesser amounts of ink. The apparant location of minutiae, particularly bifurcations, can move along the direction of the ridge as a result of digital filtering in the reader. A crude analogy is the way that the cutting point of a pair of scissors moves toward or away from the end of the blades by an amount that is large compared to the motion of the blades toward or away from each other. The paper fibers on an uncalendered fingerprint card introduce a measure of fuzziness, or noise, to the image and adds to the uncertainty of the position at which a minutia is located.

Figure 10 is a 20x photomicrograph of a portion of a print

on CNO 11 showing three alternate positions at which the reader might detect a minutia. Here, the feature that bridges between the two ridges is believed to make it unlikely that the minutia would be detected as a ridge ending; one of the two more widely displaced bifurcation locations would probably be reported.

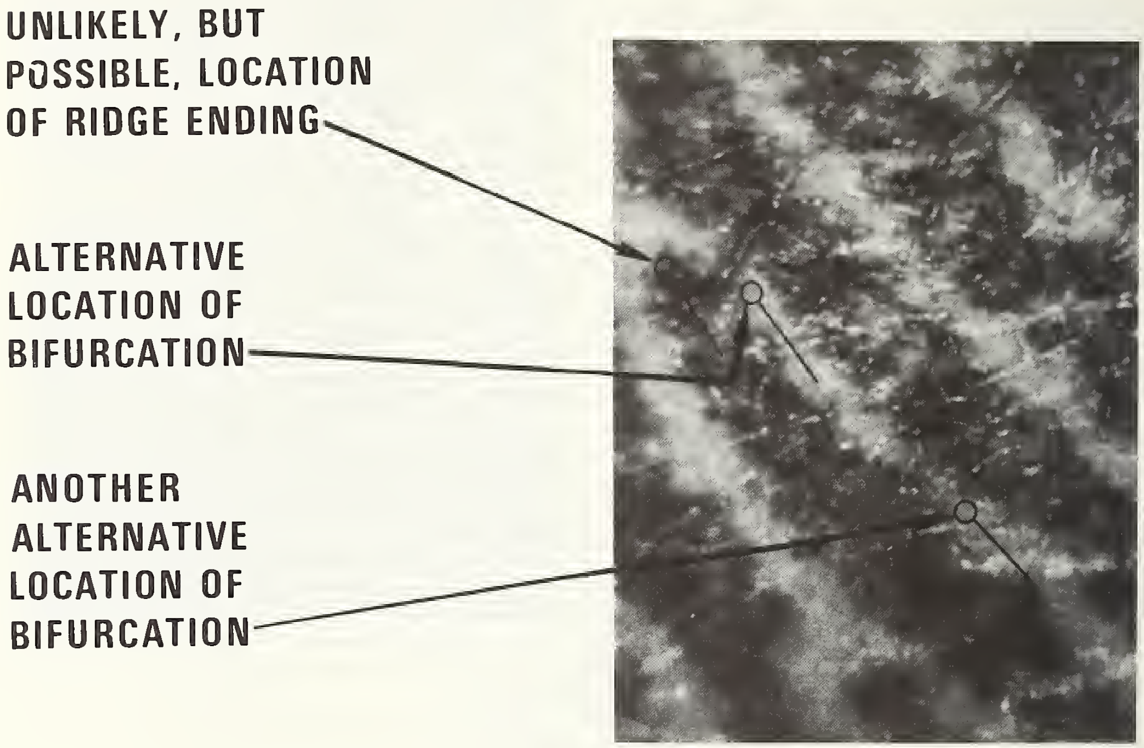

Figure 10. CNO 11

Figures 11 through 32 are copies of photomicrographs of samples of each of the fingerprint cards. In most instances, finger No. 6 was selected as the subject. This was simply because that finger was relatively easy to position under the objective lens of the microscope. These pictures were made at an enlargement of 20x, and all of them were made using two different exposure settings; the left hand photo was made using a constant setting and the right hand photo was taken with one stop lower exposure. This provides a much more dramatic demonstration of differences in contrast than do the PCS values from the diffuse reflectance measurements.

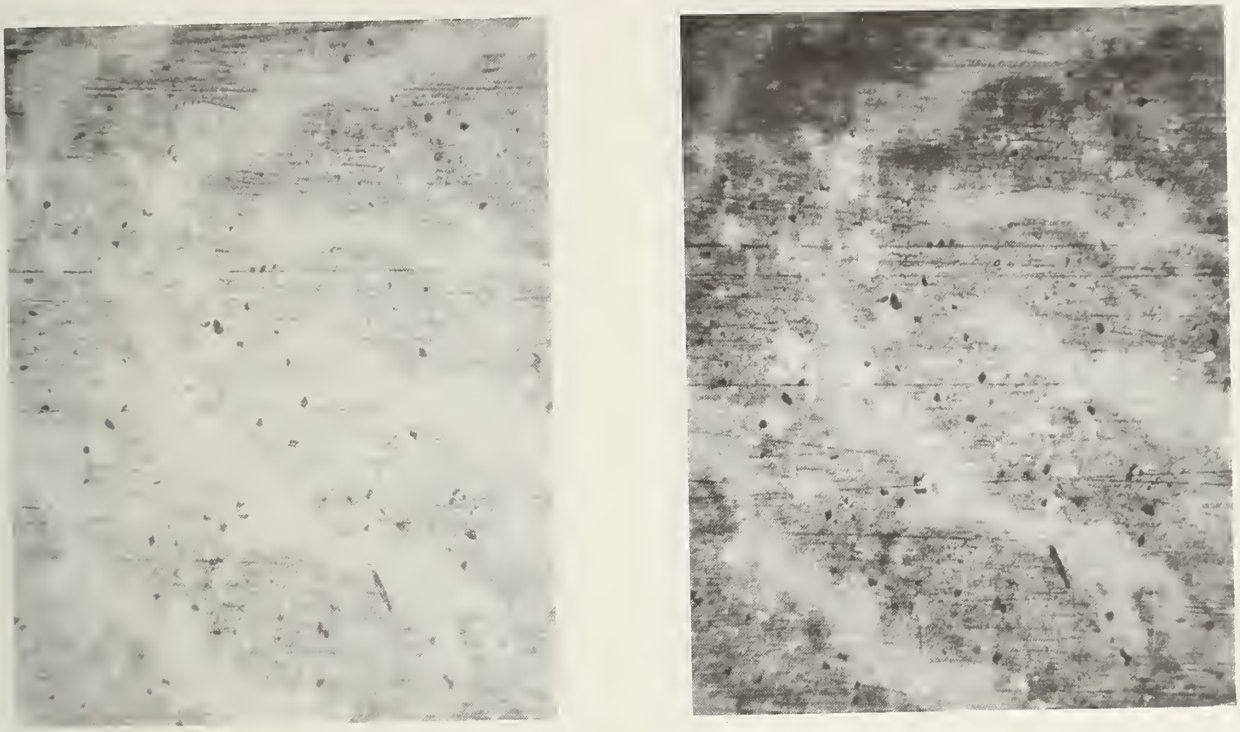

Figure 11. CNO 0, Inkless process on St. Paul calendered card.

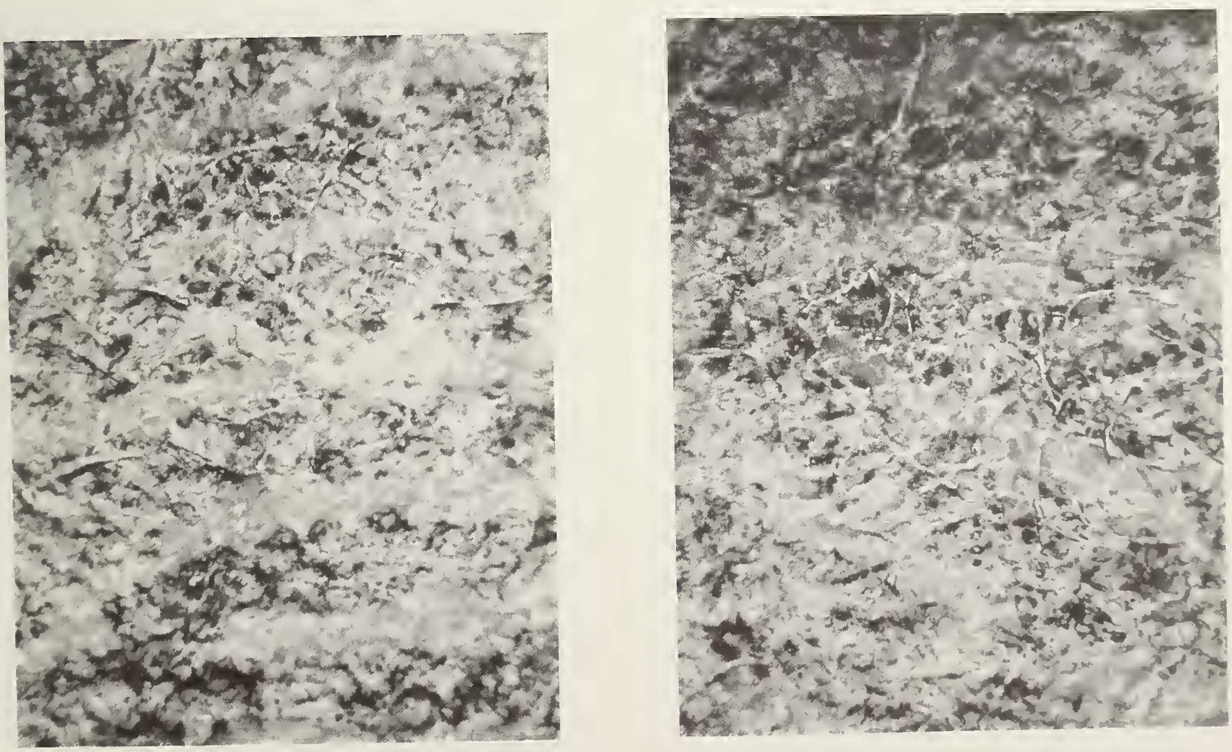

Figure 12. CNO 1, Inkless process on Calendered FBI card.

Figure 13. Inkless process on brush coated FBI criminal card.

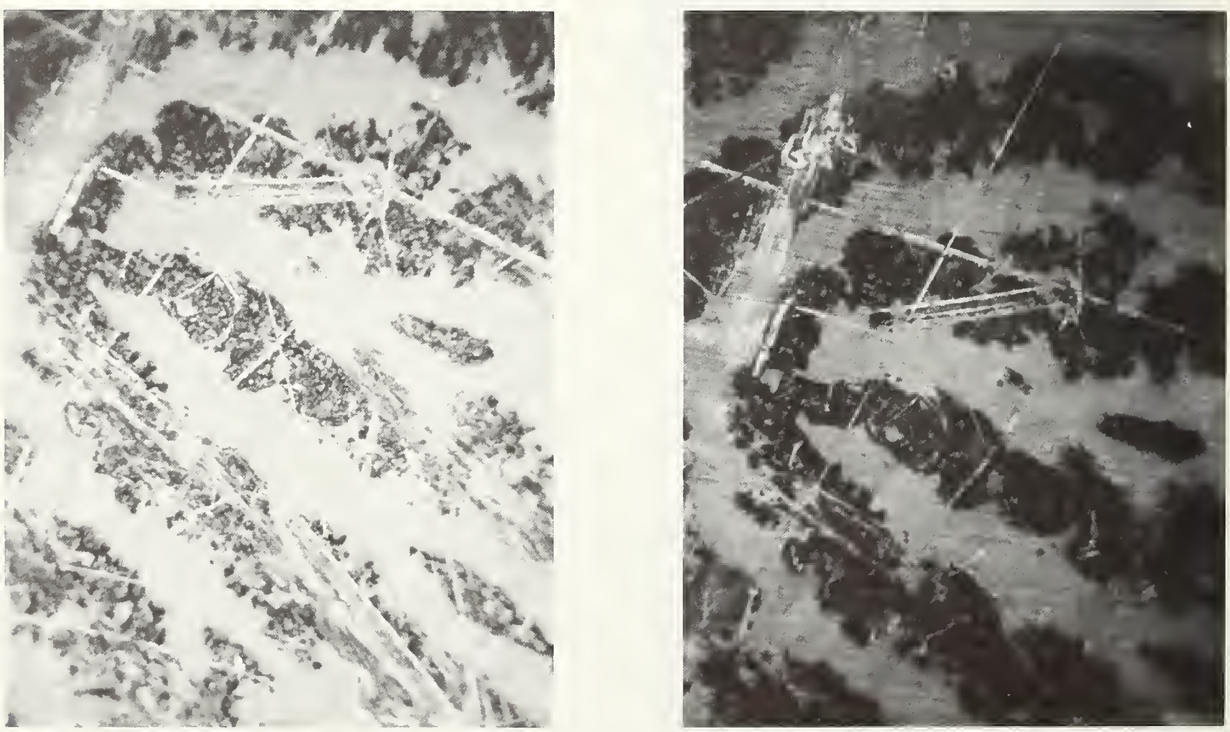

Figure 14. CNO 3. Pre-inked plastic strips, St. Paul card.

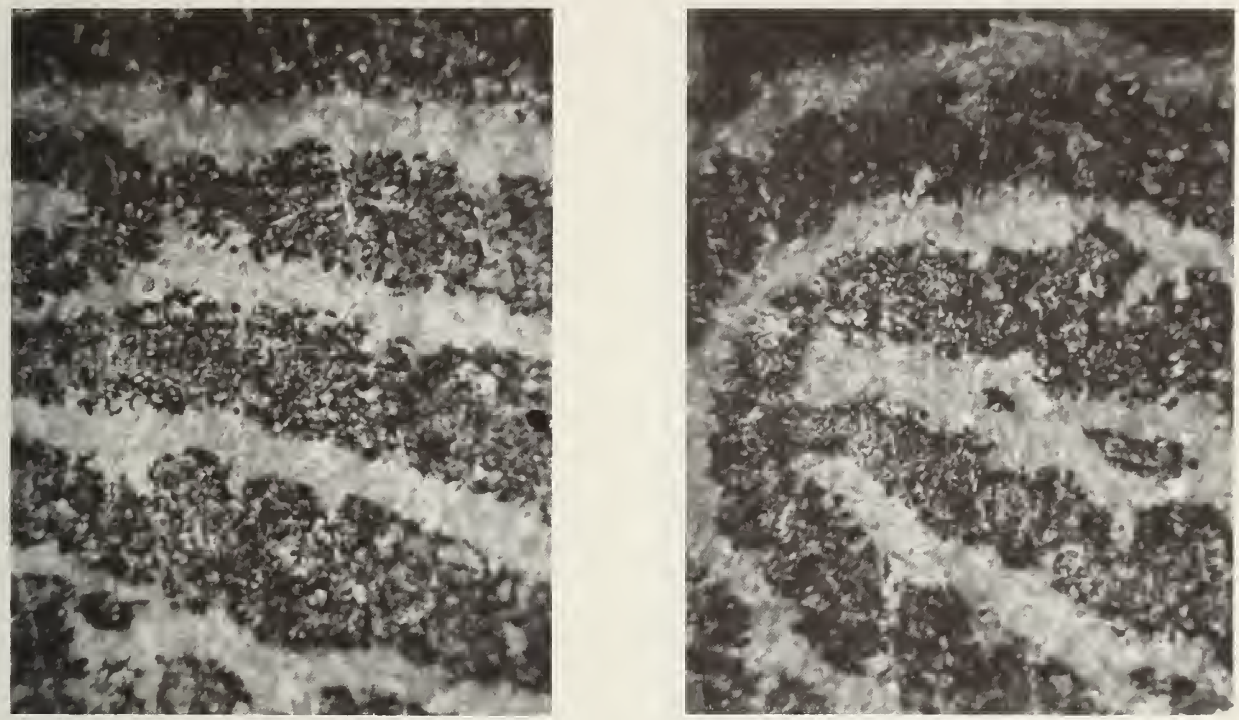

Figure 15. CNO 4. Pre-inked strips, calendered FBI card.

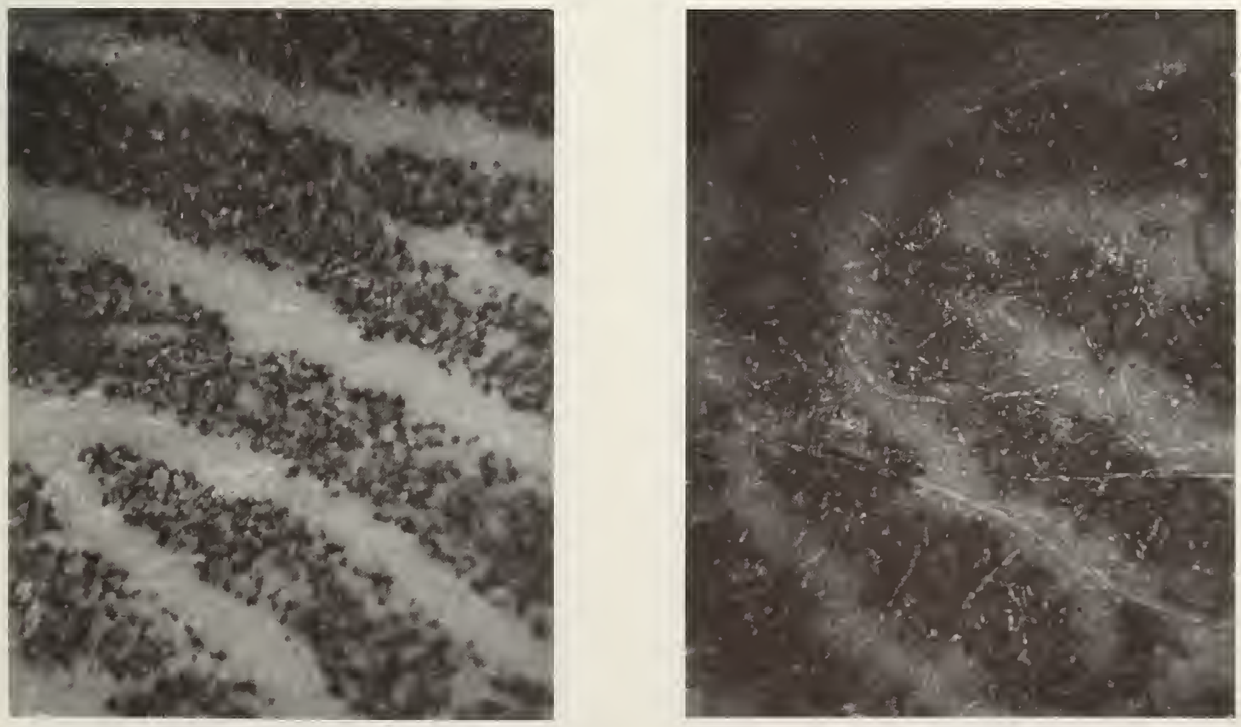

Figure 16. CNO 5. Pre-inked plastic strips, FBI criminal card.

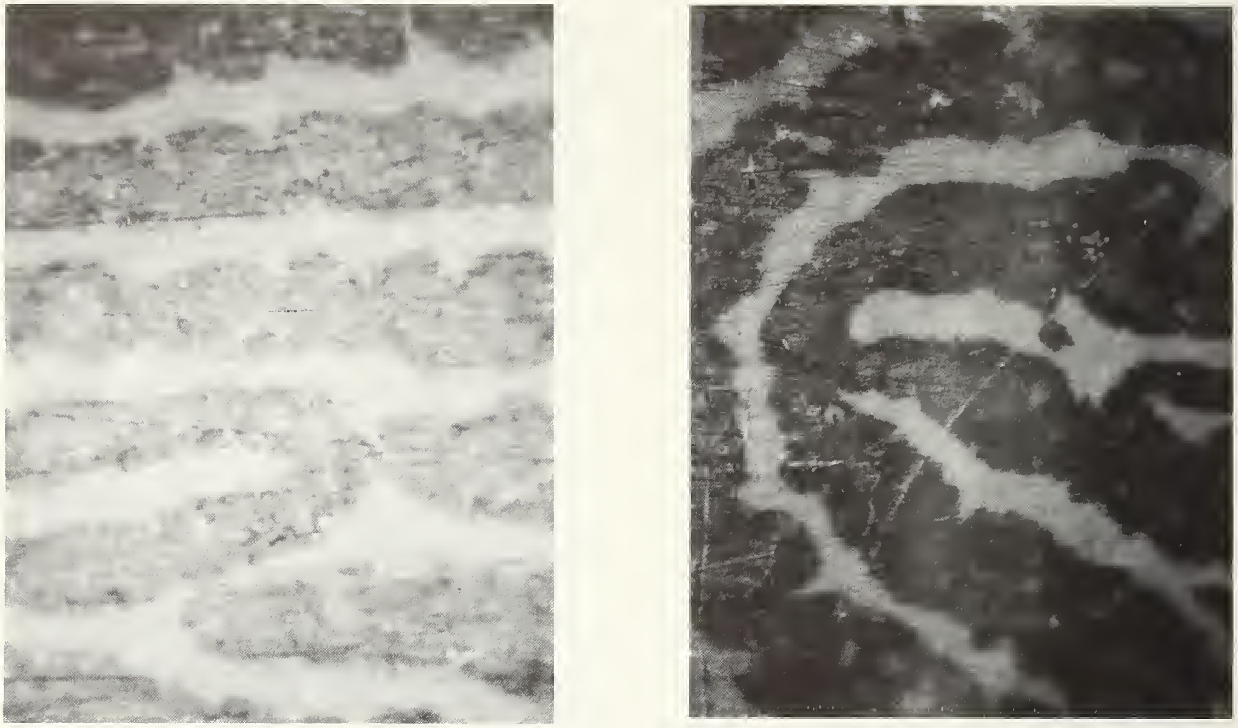

Figure 17. CNO 6. Porous pad, St. Paul card.

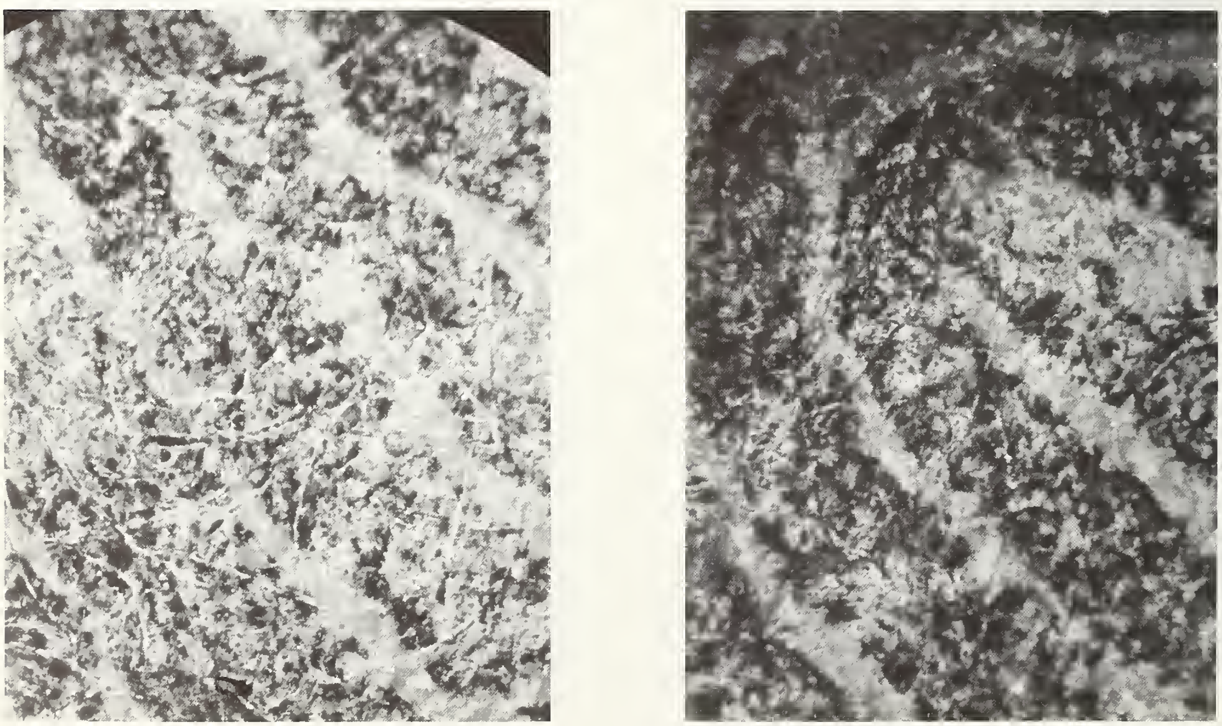

Figure 18. CNO 7. New porous pad, calendered FBI card.

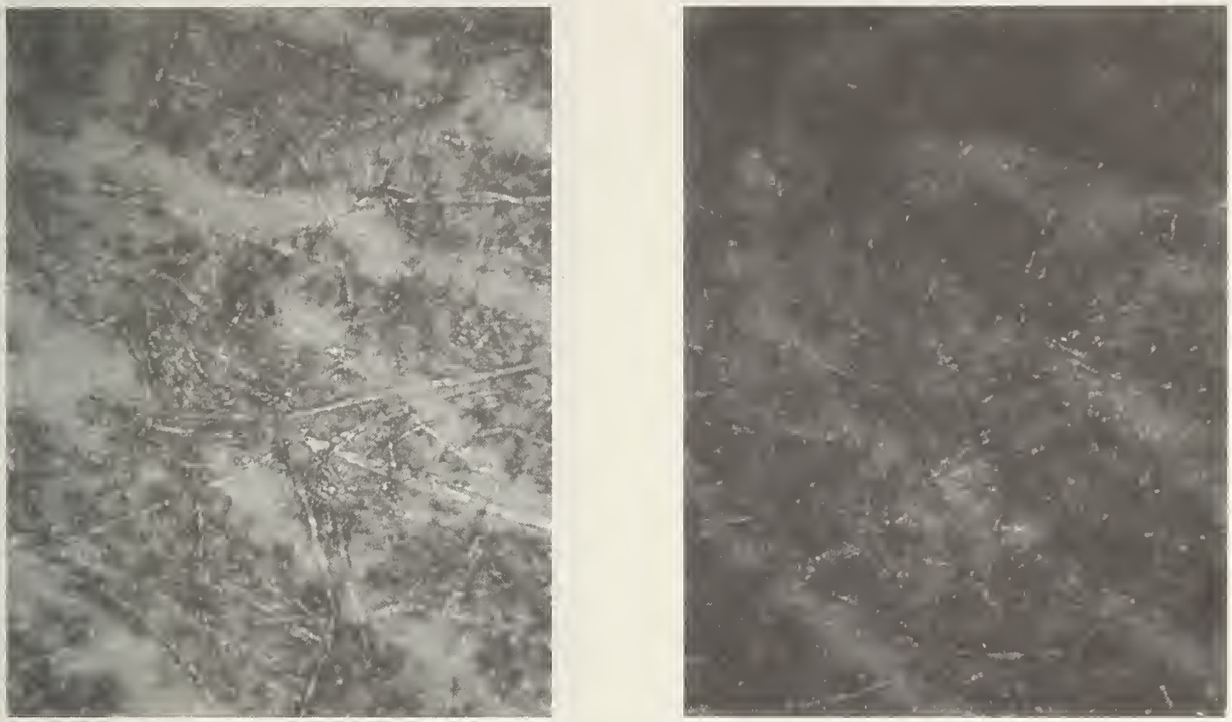

Figure 19. CNO 8. New porous pad, FBI criminal card.

Figure 20. CNO 9. Old porous pad, St. Paul card.

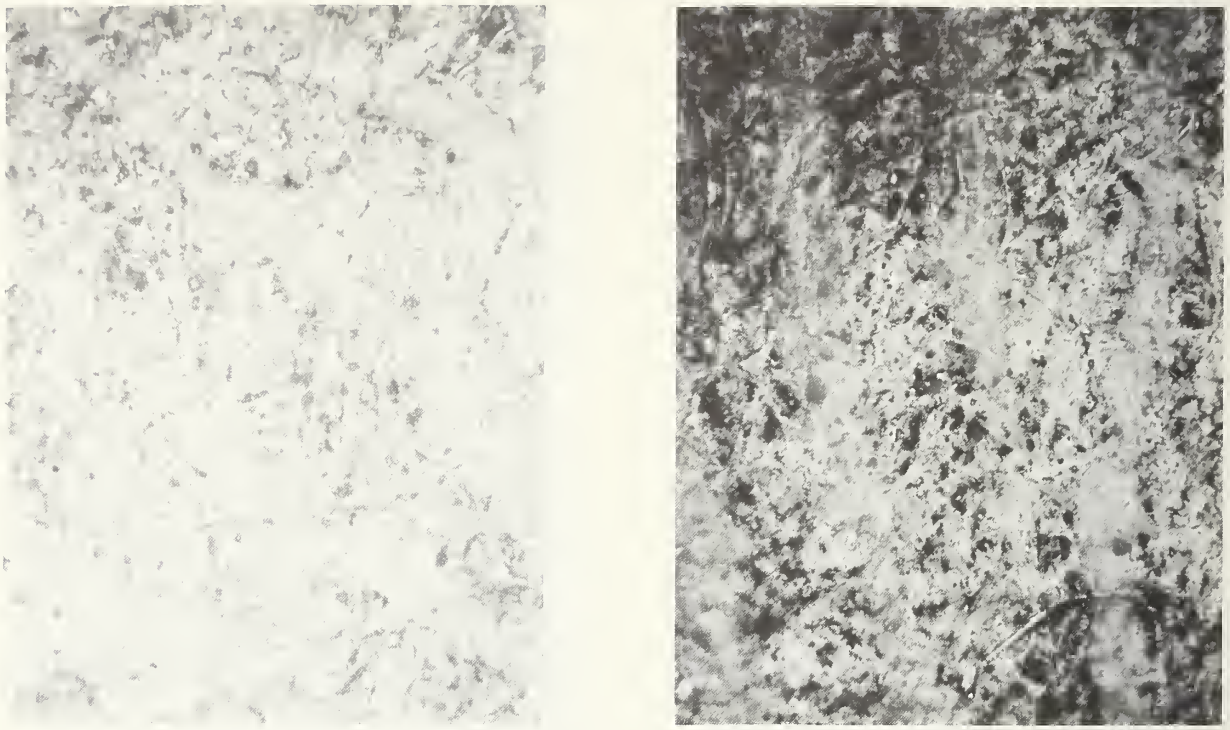

Figure 21. CNO 10. Old porous pad, calendered FBI card.

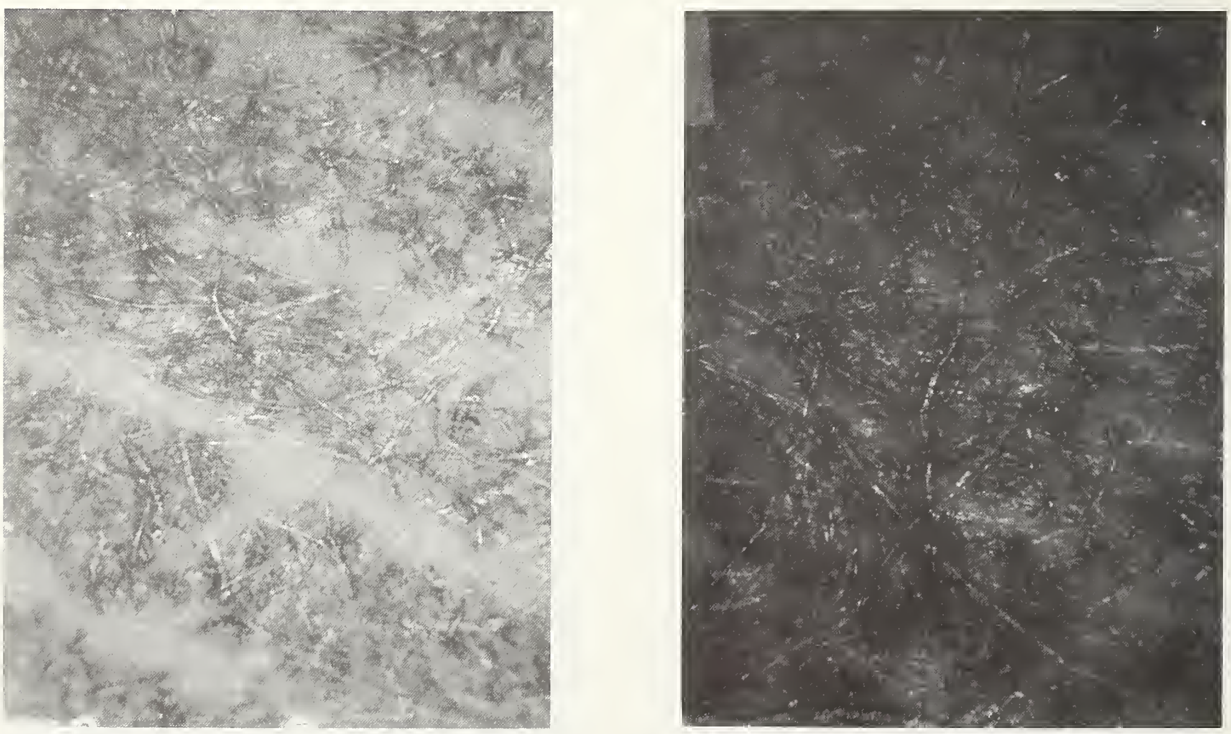

Figure 22. CNO 11. Old porous pad, FBI criminal card.

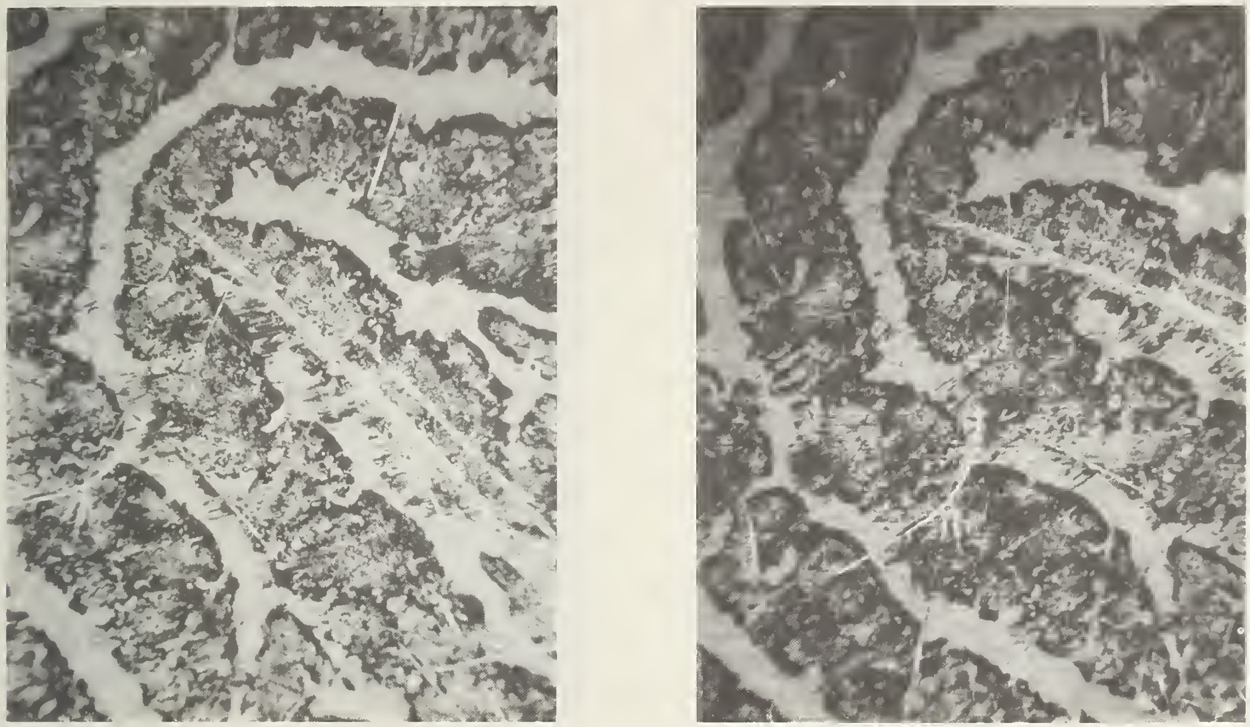

Figure 23. CNO 12. Ink on glass, St. Paul card.

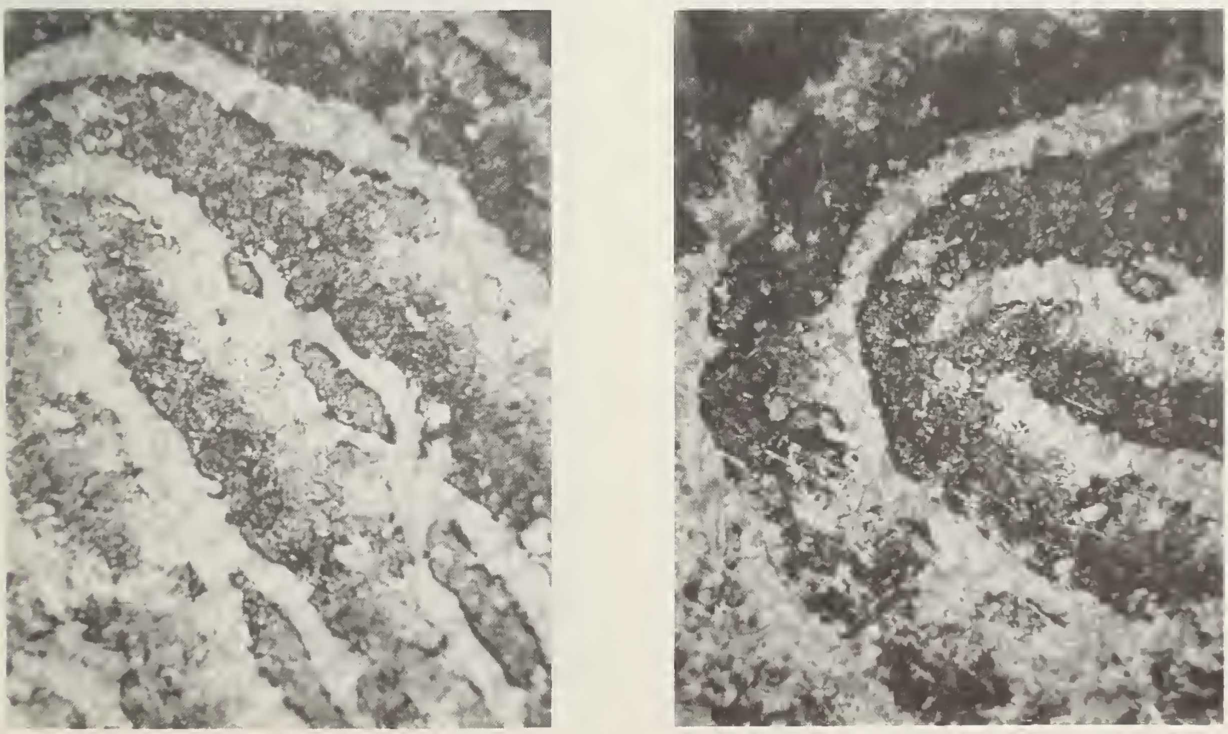

Figure 24. CNO 13. Ink on glass, calendered FBI card.

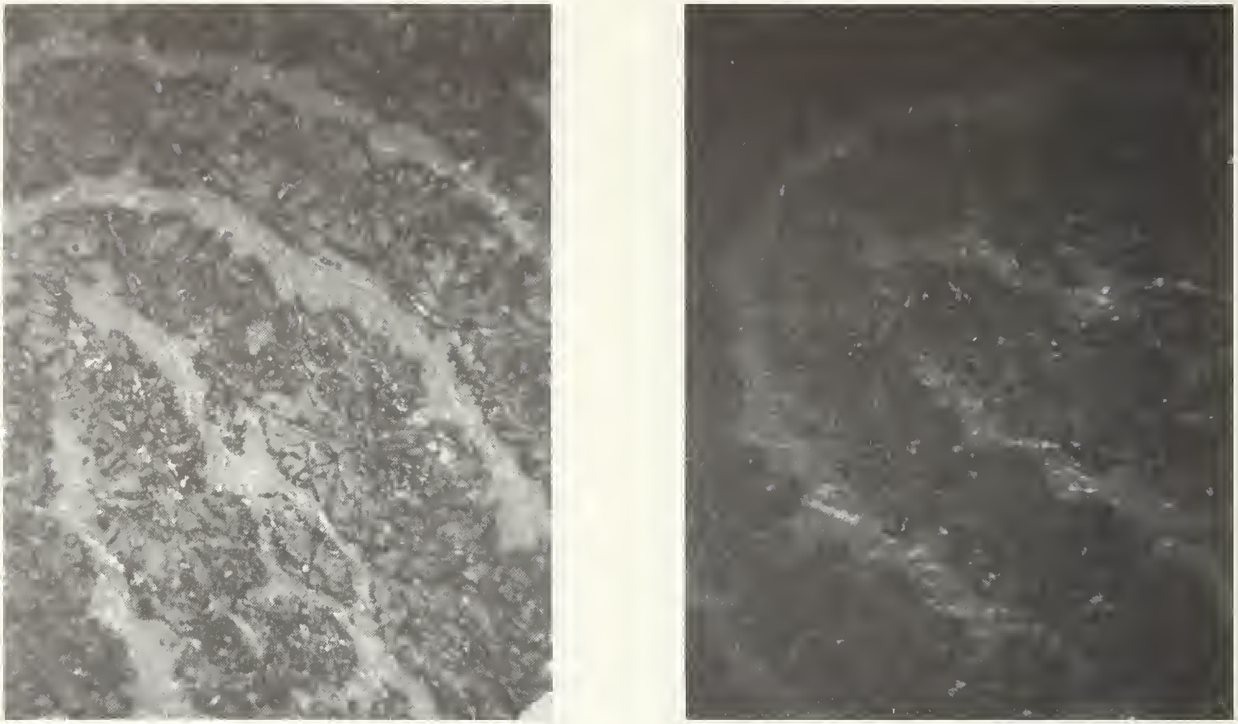

Figure 25. CNO 14. Ink on glass, FBI applicant card.

Figure 26. CNO 103. Pre-inked plastic, St. Paul card.

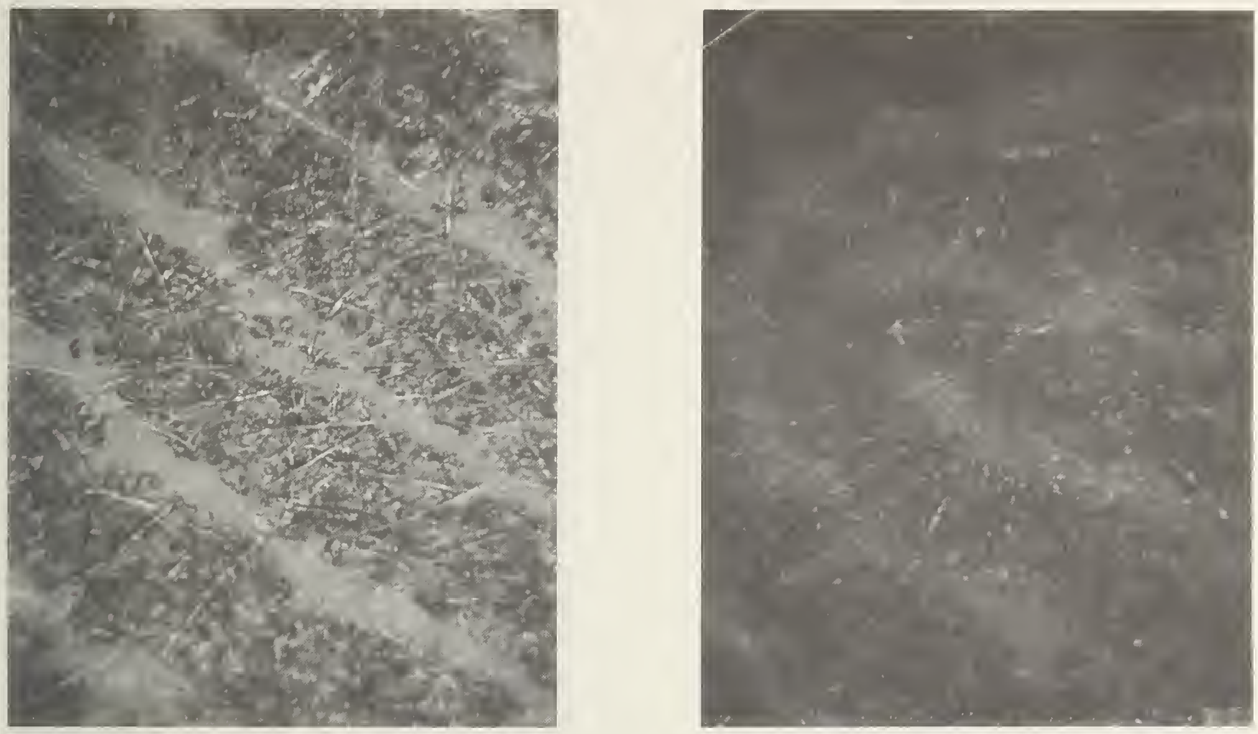

Figure 27. CNO 105. Pre-inked plastic, FBI criminal card.

Figure 28. CNO 114. Ink on glass, FBI applicant card.

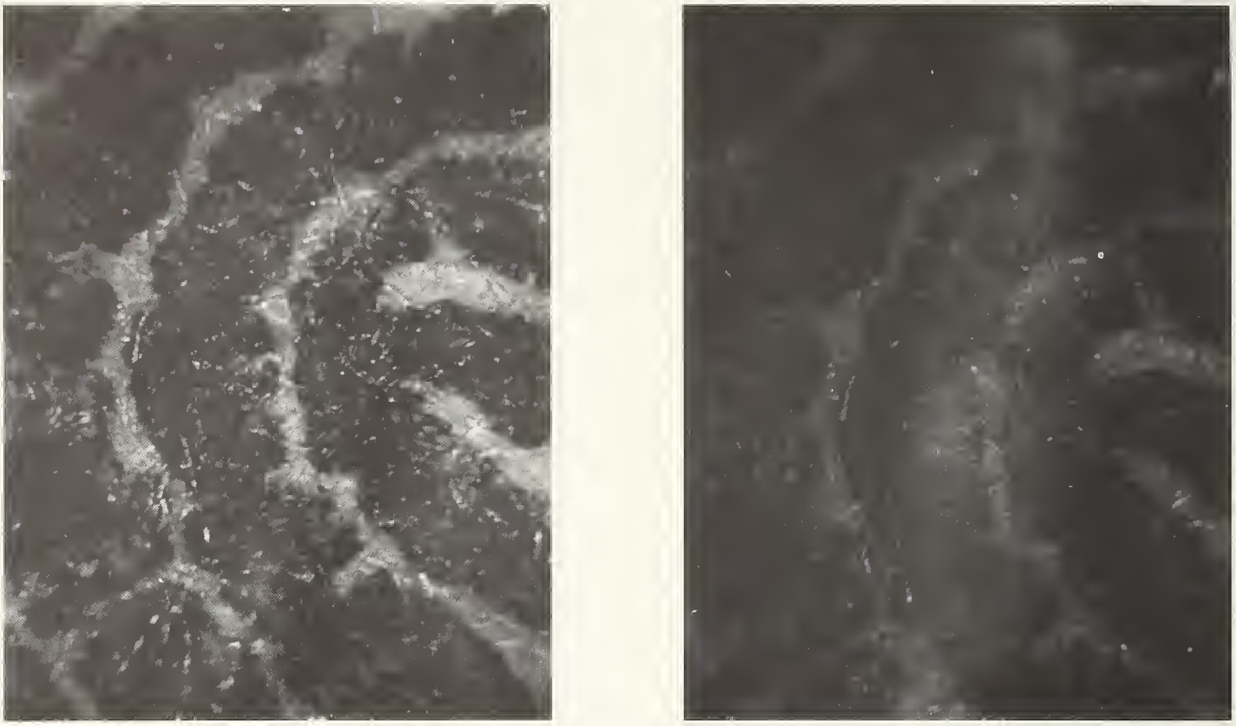

Figure 29. CNO 115. Ink on glass, FBI criminal card.

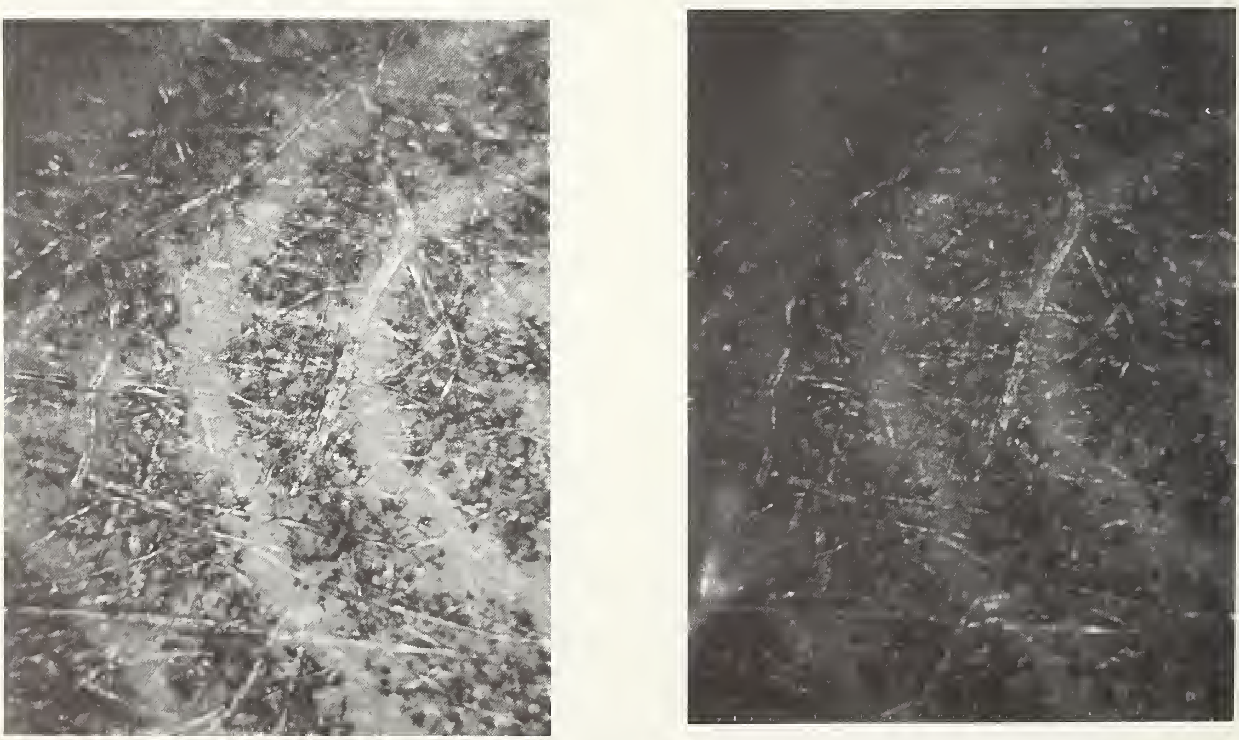

Figure 30. CNO 116. Pre-inked plastic, FBI applicant card.

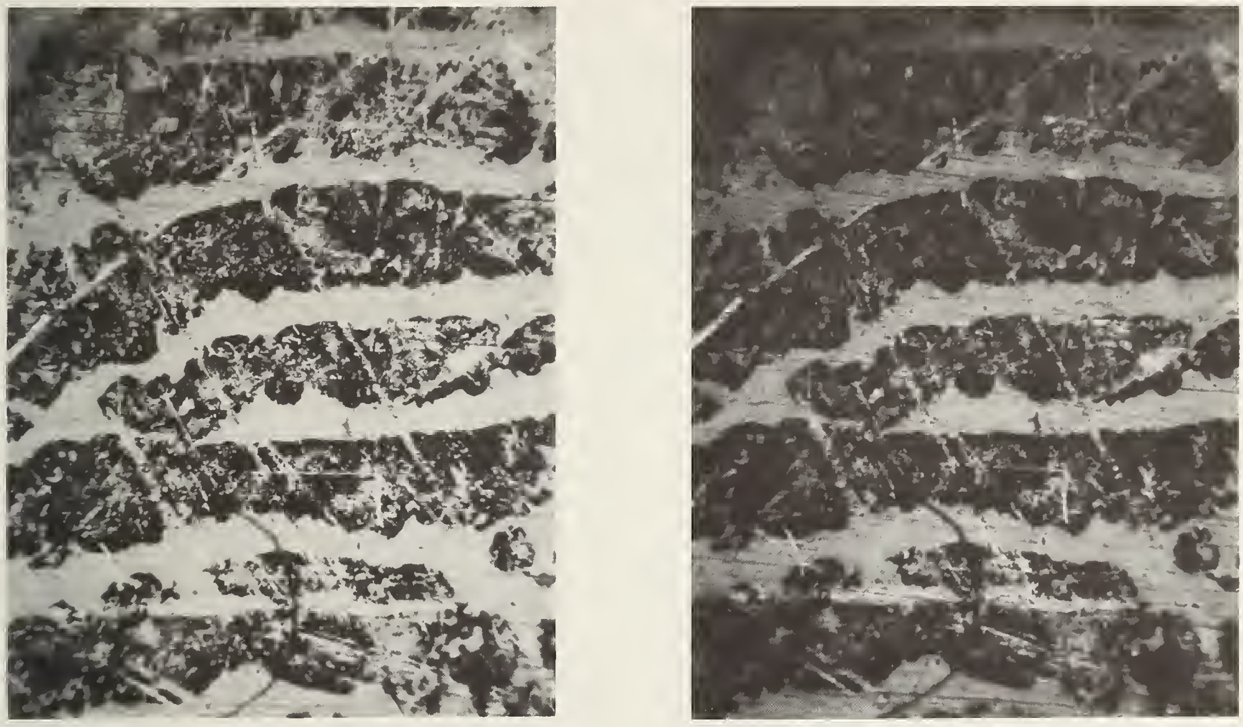

Figure 31. CNO 112. Ink on glass, St. Paul card.

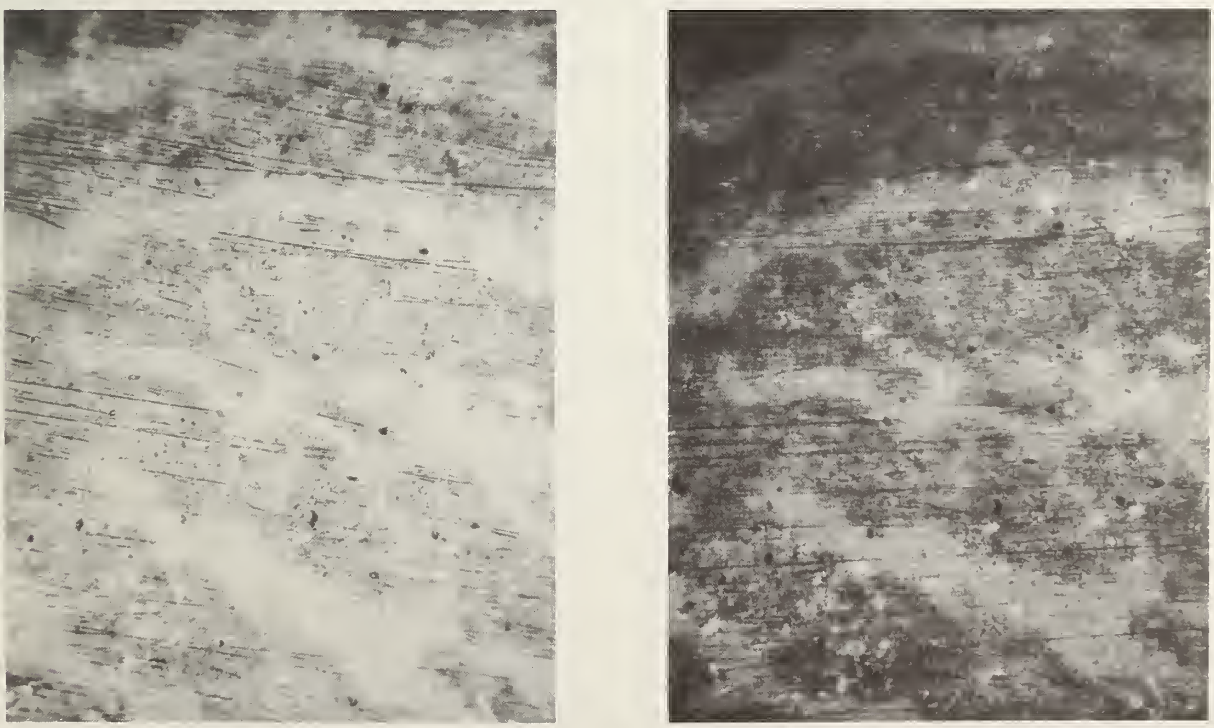

Figure 32. CNO 0. Inkless process, St. Paul card.

SMEARING RESISTANCE

Historically, fingerprints have been used for identification in a manual process that involved much physical handling of the fingerprint cards. The resistance of fingerprint images to smearing as a result of this handling was an important consideration, and it is expected to remain so in the future since a considerable amount of handling and card-to-card contact will also be involved in an automated system.

A subjective smear test was conducted on the first group of cards early in March 1981, more than two months after that first group of cards had been impressed with fingerprints. This test was intended to provide a rough estimate of the card's ability to withstand handling as demonstrated by resistance to smearing of the fingerprint images. Each fingerprint card was placed on a flat table and held firmly. Then a clean uninked finger was dragged firmly across the image in fingerbox number five or ten using a downward force of about 1.0 newton (5.0 lbs.). The image was then examined for evidence of smearing. An ordinary rubber pencil eraser was also rubbed against the image to assess its permanence this way. A Subjective Smear Resistance (SSR) value ranging from zero (poorest performance) to three (best) in accordance with the following descriptive scale:

SSR	Description
0.	Image badly smeared by finger, and probably unusable except by a latent fingerprint examiner. Image easily and completely erased with pencil eraser.
1.	Image noticably smeared by finger. Image significantly degraded but possibly still useable. Image easily erased with pencil eraser but leaves a faintly visible residue.
2.	Slight smear observable from finger, but image not significantly damaged. Image slightly resists ordinary pencil eraser.
3.	No evidence of smearing produced by finger. Image strongly resists ordinary pencil eraser.

Table X shows the SSR values that were assigned to each of the cards in the first group.

TABLE X

CNO	SSR
1	3
2	3
3	1
4	0
5	2
6	3
7	3
8	3
9	3
10	3
11	3
12	1
13	0
14	1

Then, even though they had not aged the same amount, CNO 115 and 116 were tested for SSR and each assigned a value of two.

No smearing was observed on any of the cards having images produced by the inkless chemical process, or images produced using either of the pre-inked porous pads. Some slight evidence of smearing was observable on images that had been produced using the pre-inked plastic strips. This limited smearing was somewhat more noticable on the calendered card stock than on the uncalendered stocks.

The greatest amount of smearing occurred on those images that had been produced from ink on glass. The degradation to the images was judged to be unacceptably great on both the calendered and on the uncalendered card stock.

SUMMARY OF PERFORMANCE

Table XI shows the summary of the experimental results grouped by type of inking process and Table XII shows the results grouped in accordance with the type of card stock.

TABLE XI

PRE-INKED PLASTIC FILM STRIPS

CNO	CARD STOCK	1 FING. MEAN	SSR	AVERAGE
3	St. Paul Calendered	1,387	1	
103		658		
4	Calendered FBI (Crim.)	826	0	
5	Standard FBI (Crim.)	817	2	
105		507		
116	Standard FBI (Appl.)	361	2	
				759

PRE-INKED POROUS PAD

CNO	CARD STOCK	1 FING. MEAN	SSR	AVERAGE
6	St. Paul Calendered	723	3	
9		887		
7	Calendered FBI (Crim.)	662	3	
10		450		
8	Standard FBI (Crim.)	82	3	
11		53		
				476

INK ON GLASS

CNO	CARD STOCK	1 FING. MEAN	SSR	AVERAGE
12	St. Paul Calendered	330	1	
112		897		
13	Calendered FBI (Crim.)	211	0	
115	Standard FBI (Crim.)	246	2	
14	Standard FBI (Appl.)	76	1	
114		52		
				302

TABLE XII

ST. PAUL CALENDERED CARD

CNO	INK	1 FING. MEAN	SSR	AVERAGE
3	Pre-inked Plastic Strip	1,387	1	
103	"	658		
6	Pre-inked Porous Pad	72	3	
9	"	887		
12	Ink on Glass	330	1	
112	"	897		
				914

CALENDERED FBI CRIMINAL CARD

CNO	INK	1 FING. MEAN	SSR	AVERAGE
4	Pre-inked Plastic Strip	826	1	
7	Pre-inked Porous Pad	662	3	
10	"	450		
13	Ink on Glass	211	0	
				531

STANDARD FBI CRIMINAL CARD

CNO	INK	1 FING. MEAN	SSR	AVERAGE
5	Pre-inked Plastic Strip	817	2	
105	"	507		
115	Ink on Glass	256	2	
8	Pre-inked Porous Pad	82	3	
11	"	53	3	

STANDARD FBI APPLICANT CARD

CNO	INK	1 FING. MEAN	SSR	AVERAGE
116	Pre-inked Plastic Strip	361	2	
14	Ink on Glass	76		
114	"	52	1	
				212

The cards using the inkless chemical process have not been included in these summary tables because of the relatively poor matching scores that they produced.

ACCELERATED AGEING EXPERIMENTS

Exposure to elevated temperature is often a useful technique for simulating accelerated ageing. To a first approximation, each ten degrees Celsius that the temperature is elevated doubles the ageing rate as compared with the ageing rate of an unheated specimen. Using this rule, for example, an hour of exposure at a temperature that was 50 degrees C. above ambient, would be approximately the equivalent of thirty-two hours of exposure at ambient. The process is not believed to be linear (at least in tests on paper) as the ageing process slows with the passage of time at elevated temperatures.

An accelerated ageing test using elevated temperature was conducted on the fingerprint cards which were used in these experiments. All 21 of the cards from both sets were placed in a temperature controlled oven. They were stacked with a small air space between each card. This was provided by using thin steel strips as spacers between cards. The strips were laid along the right and left edges of the cards. A fan in the oven operated continuously and circulated air around and between the horizontally stacked cards. The oven temperature was maintained at 125 degrees C. This was approximately 100 degrees C. above ambient, and using the rule of thumb described above, should accelerate initial ageing by a factor of 1024.

After 48 hours at the elevated temperature, the cards were removed from the oven. Diffuse reflectivity measurements were made on CNO 1 - 14 and compared with the values that were made on these cards before and reported in Table IV. The diffuse reflectance of the card stock (DRs) was lower on all specimens. The greatest changes occurred in CNO 1 and 2 (the inkless chemical process). On these two cards, the chemical that had been used to treat the card stock showed very pronounced discoloration, and the values of DRs were reduced to 53 to 55 percent of their original values. All of the other cards showed much less discoloration and the values of DRs were only reduced to about 90 to 92 percent of their original values.

No recognizable changes in the values of the ink reflectance (DRi) were observed.

After these reflectance measurements were made, the cards were returned to the oven and held at 125 degrees C. for an additional 73 hours. Then they were returned to ambient temperature and the value of DRs was determined. Only a small further reduction in DRs was observed and nearly all of the cards showed a final diffuse reflectance of about 87 or 88

percent of their original values. The St. Paul calendered stock had a final DRs value of 0.82, and the chemically treated stock (CNO 1 and 2) was unchanged at DRs values of 0.46 and 0.42 respectively. The remaining cards all stabilized out at DRs values of 0.75 to 0.77.

After the measurements of diffuse reflectance had been completed, the cards were read again by the automatic fingerprint reader system. They were again matched and the scores were compared with the scores developed by the same cards prior to the accelerated ageing process. The results are shown in Table XIII.

TABLE XIII

CNO	1 FING. MEAN RS	STD. DEV.
0	114	24%
1	427	41%
2	158	34%
3	1,286	24%
4	740	37%
5	975	20%
6	477	32%
7	608	28%
8	58	28%
9	563	40%
10	465	45%
11	54	66%
12	168	42%
13	196	39%
14	99	41%
103	344	25%
105	477	28%
112	593	26%
114	39	47%
115	125	36%
116	385	24%

Comparison of these data with those shown in Table IV reveals that the artificial ageing process had reduced the diffuse reflectivity of the card stock for all specimens, and as a consequence lowered the print contrast signal. The

matcher socres, however, have not always been reduced by a proportionate amount. In fact, in a few instances, the matcher scores were actually higher after the artificial ageing process than they were on the newly inked cards. In most of these cases where the matcher scores have increased, the standard deviation of the score has also increased markedly. For example, the CNO 10 score increased by three percent, but the standard deviation of the scores went from 28% to 45%, an increase of 62%.

On the whole, the specimens using the St. Paul calendered card stock developed scores that were reduced by about 40% as a result of the artificial ageing. The calendered FBI criminal cards showed a score reduction that was much smaller, typically less than 10%. The standard FBI cards, both criminal and applicant yielded indeterminate score results. On some specimiens the score was higher and on others it was lower. CNO 5 and CNO 105 from this group are particularly interesting. The score for CNO 5 showed an increase of 19% after ageing, and the standard deviation decreased from 24% to 20%. The CNO 115 score only dropped 6%, and here again, the standard deviation was less after ageing.

CONCLUSIONS

I. Significant improvements in matching scores can be obtained through the use of calendered card stock for taking impressions of fingerprints. The St. Paul stock is superior to any other tested, however, it is only smear resistant when used with the porous pre-inked pads. The scores developed from specimens using this card stock were significantly reduced by the accelerated ageing process, but even after this reduction they were still high enough to yield excellent performance.

II. Pre-inked film strips provide much better image quality (as indicated by higher matching scores) than any of the other inking processes that were tested. They were the only inking process that provided consistently good results with the standard FBI criminal card stock. They demonstrated poor resistance to smearing on calendered card stocks.

III. Pre-inked porous pads yield reasonable scores on calendered card stocks, but are considered to be quite inferior when used with the standard FBI card stock. Their resistance to smearing was excellent, however, and if they are used with a calendered stock, they probably are the best all round compromise for cost, availability, score and smear resistance.

IV. Ink on glass provides the lowest scores of any of the inking processes. In addition, the results are highly variable and do not provide the best smear resistance.

V. The standard FBI applicant card stock that was used in these experiments developed average scores only two-thirds as high as the criminal card stock.

Figure 33 shows a summary of the score performance of the preferred combinations of card stock and inking process. The original scores are shown as a solid line, and the scores after artificial ageing are shown by a dotted line. CNO 6 and CNO 9 are pre-inked porous pad on St. Paul calendered stock, and CNO 7 and CNO 10 are on calendered FBI criminal card stock. CNO 5, 105 and 116 are scores produced by the use of pre-inked film strips on standard FBI card stocks.

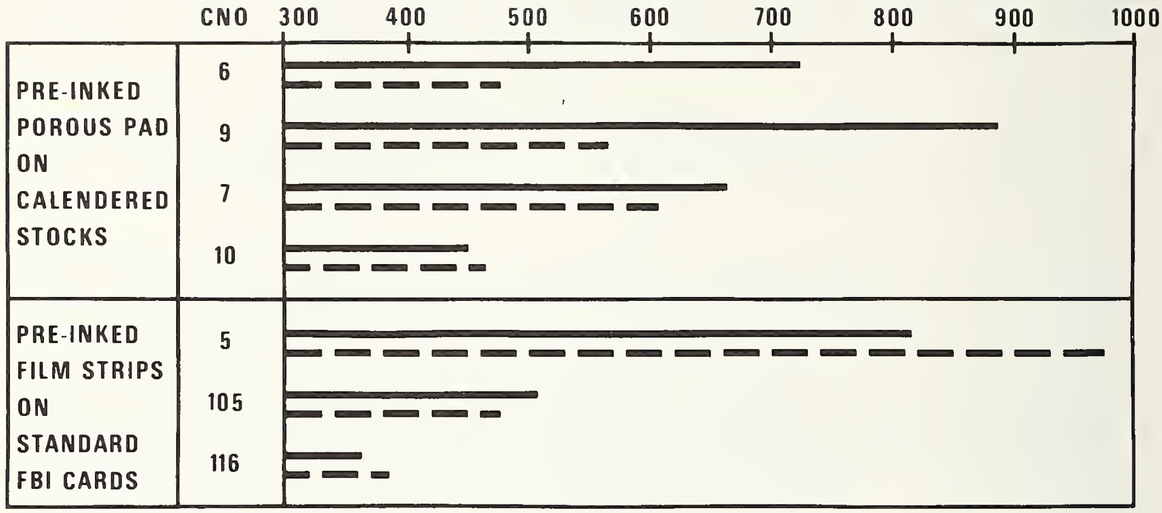

Figure 33. Scores of preferred card stocks and inking processes.

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

A series of experiments were conducted to determine the variation in the scores developed using a matching algorithm designated as the M-82 for mating fingerprints of different image quality that had been read by the Automatic Fingerprint Reader System (AFRS) of the FBI. The variations in image quality resulted from the use of a variety of card stocks and recording techniques to record the print of a single finger. For each image recording process, a sample of 56 finger-pairs were matched and mean single-finger score values were developed. These varied over a factor of more than 70 to one. The best scores were developed from images placed on very white, slick appearing, calendered card stock with the use of film strips that had been pre-inked and which could be separated to expose an ink film of predetermined thickness and uniformity. This combination had less resistance to smearing than fingerprints produced on the same stock from the use of a pre-inked porous pad. However, the latter still produced acceptably high scores.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

fingerprint cards; fingerprint images; fingerprint ink; image quality

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